Clinical Medicine

Patterns of Cervical Spine Injury and Their Associated Lesions

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Motorcycle riding and diving into shallow water continue to present a high risk of cervical spine injury, often complicated by spinal cord damage. In patients with high cervical cord trauma, differentiation of arterial hypotension due to losing vasomotor control from the effects of internal hemorrhage can cause difficulty. In a series of 123 consecutive cases of cervical spine injury, no evidence was found that either early surgical treatment or steroid administration exert a favorable influence on recovery from traumatic myelopathy. When compared with other series, differences were found in the nature, frequency and severity of both spinal and associated injuries, resulting from the relative frequency among the population studied of trauma due to a particular mechanism—traffic accident, diving, industrial injury—and the special functions and location of the hospital from which information is gathered.

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Cervical spine trauma represents an important cause of mortality and morbidity, particularly in young people. Over the years the clinical features of several large series of cases have been reported from both the United States[1-5] and other countries.[6-8] In this article we review our experience with patients with this injury admitted to our service during a six-year period and compare our findings with others recently reported, identifying some features of the injury that remain relatively constant between series and others, such as the incidence of associated injuries, that are more variable.[7,9-12]

Patients and Methods

We examined the records of 148 patients admitted to the University of Arizona Health Sciences Center between January 1, 1980, and December 31, 1985, in whom a tentative diagnosis of acute injury to the cervical spine or spinal cord had been made. Whenever there was a discrepancy between the initial and final radiologic diagnoses, the original films were reviewed with a radiologist. Excluded were 23 patients suffering only from an uncomplicated ligamentous strain and 2 patients having generalized metastatic disease who presented with neck pain due to pathologic fracture of the cervical spine without a clear history of trauma.

The remaining 123 patients were divided into two groups according to the severity of their spinal injury. Considered as major injuries were all those that required hospital admission, including all instances of neurologic deficit and those that required the application of halo traction or other immediate surgical treatment. Patients with minor injuries were those needing no more treatment than the application of a Philadelphia collar, having no neurologic complications and admitted to hospital because of associated injuries or pending an appropriate disposition.

Six categories of major associated injury were established for each group: intracranial damage, other skull or facial fractures, injuries to the rest of the spinal column, rib fractures and intrathoracic injuries, intra-abdominal and pelvic visceral lesions and limb injuries with fractures or neurovascular lesions (or both). All other associated injuries were regarded as minor.

Statistical comparisons of the ages of subjects were made using the Mann-Whitney nonparametric test. Other comparisons were made using the χ^2 test. For simplicity, only the P values resulting from these tests are shown.

Results

General Features

Of the 123 patients, 97 were male (79%) and 26 female (21%), having an age range of 5 to 83 years and a median age of 26 years (mean 30 years). A total of 93 patients (76%) suffered major cervical spine injuries as previously defined, and there were 30 (24%) minor cervical injuries. The median hospital stay of all patients was 8 days (mean 14 days); 6 (5%) died in the hospital, 19 (15%) were transferred to skilled or intermediate care facilities and 98 (80%) returned home.

Etiology

Most patients (100/123; 81%) were injured as a result of traffic accidents. Of 91 cases in which adequate details of the accident were given, 11 (12%) occurred to persons riding motorcycles (10 drivers and 1 passenger) and 5 (5%) to pedestrians. Two patients received additional injuries when assaulted by a person traveling in another involved vehicle!

Falls from a building (or scaffold) accounted for six injuries (5% of the whole series) and there were two industrial accidents. Three adults (2%) suffered gunshot wounds. Of nine patients injured during sports, seven (6%) were injured while diving or jumping into swimming pools, one was a boy who headed the ball while playing soccer and one was thrown while wrestling.

Nature of spinal injury. The levels of fracture or dislocation in the cases of major cervical injury are shown in Table 1.

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The minor cervical injuries included various degrees of undisplaced fracture through a lamina or of the anterior margin of a vertebral body and fractures of transverse or spinous processes.

A cervical spinal cord injury occurred in 27 patients (22% of the whole series; 28% of those with major cervical lesions), the injury being complete or almost complete in 13 cases (48% of those with cord damage); the frequencies of the various neurologic syndromes are shown in Table 2. In two instances patients with cord lesions had evidence of nerve root damage as well, while five patients—5% of major injuries—sustained a traumatic radiculopathy without myelopathy. Among the major cervical spinal injuries, spinal cord damage was significantly ($P < .01$) more frequent in the patients suffering subluxations or dislocations of the cervical spine (17/34; 50%) than in those with fracture alone (7/56; 13%). It was also significantly more frequent ($P < .001$) in patients whose bony injury lay between C-5 and C-7 (20/49 cases; 41%) than in those with bony injuries between C-1 and C-4 (4/41 cases; 10%). The difference between the ages of the patients who did (mean 30 years) and did not (mean 31 years) suffer a spinal cord injury was not significant ($P = .6$, Mann-Whitney).

The two youngest patients in this series, aged 5 and 16 years, both sustained spinal cord injuries without radiologic abnormality.[13] One previously asymptomatic 56-year-old patient having severe spondylosis with spinal stenosis sustained a hyperextension injury without fracture or dislocation but with temporary quadriparesis.

Associated injuries. Associated injuries were recorded in 79/123 (64%) of patients, comprising 55/93 (59%) of those who had sustained major cervical spine injuries and 24/30 (80%) of those with minor cervical injuries.

TABLE 1.—*Frequencies and Levels of Fractures and Dislocations (Including Subluxations) With or Without Spinal Cord Damage**

Level of Fracture	*C-1*	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*C-7*
Major fractures without dislocation, N=56							
Fractures, No.	14	15	5	8	21	20	14
With cord damage, No.	0	0	0	1	4	2	0
Minor fractures, N=30							
Fractures, No.	0	2	4	0	7	11	13
Level of Dislocation		*C1-2*	*C2-3*	*C3-4*	*C4-5*	*C5-6*	*C6-7*
Dislocations, N=34							
Dislocations, No.		7	1	3	6	8	9
With cord damage		1	1	1	4	4	6

*3 patients had spinal cord lesions without radiologic evidence of fracture or dislocation.

TABLE 2.—*Segmental Levels and Frequencies of Syndromes of Spinal Cord Damage**

Cord Damage	*Spinal Cord Level* C1-4	C5-7
Complete lesions	2	11
Anterior cord syndromes	1	1
Central cord syndromes	2	4
Brown-Séquard syndrome	3	1
Concussion	..	2
Total	8	19

*In 3 patients the upper neurologic level was slightly higher than the level of bony injury.

In our series, unlike that reported by Reiss and coworkers,[10] there was no significant difference ($P = .175$, Mann-Whitney) between the ages of the patients who did (mean 32 years) and who did not (mean 28 years) sustain an associated injury, nor was there any difference in the incidence of associated injuries between the patients with spinal cord damage (52%) and those without this complication (49%; $P < .6$). More of the patients injured in traffic accidents sustained associated injuries (67/100; 67%) than did those injured in other ways (11/23; 48%). The difference, however, is not formally significant ($.1 > P > .05$) and is much less striking than that recorded by Soderstrom and associates,[11] namely, 36% versus 10%.

There were 11 instances of trauma to other parts of the spinal column: 7 of these involved the thoracic spine, 2 of them being complicated by paraplegia; 3 were lumbar fractures and 1 a fracture of the sacrum.

Neither the subsequent clinical histories of the patients nor the autopsy findings in the fatal cases evidenced any major associated injuries beyond those recorded at the time of admission. One negative emergency laparotomy, however, was done for a moribund patient, regarded as in "shock," who later proved to have a complete cord transection due to a dislocation at C1-2. On a second occasion, which occurred after the conclusion of this series, a negative laparotomy was done on a patient admitted with a high cervical cord lesion who had a mean arterial pressure of 50 torr. In this case peritoneal lavage had disclosed a borderline erythrocyte count.

Management

The treatment of this series of patients followed the usual lines. In most cases a cervical collar had been applied by paramedical personnel at the scene of the injury. The patients were immediately assessed by a member of the trauma service, resuscitation was commenced and a neurosurgical consultation was done; a few gravely injured persons were transferred immediately to the operating room. All the patients who were in shock or having evidence of spinal cord damage received steroids, usually about 100 mg per day of methylprednisolone sodium succinate or an equivalent, for two to four days. We found no indication that any particular regimen of steroid therapy was associated with more or less recovery of cord function than the others.

In all, 66 patients (71% of those with major cervical spine injuries) were initially managed by skeletal traction; of these, 19 (29% of those so treated) later required fusion. Immediate intervention—reducing locked facets, decompressing depressed laminar fractures, removing extruded bony or disc material—was required in 11 cases (12% of major injuries) and elective early cervical fusion was undertaken in 11 patients. Four patients having stable fractures of the lateral mass of the atlas, one with a stable fracture of the odontoid, one with a compression fracture of the body of C-7 and two of the three with gunshot wounds, were electively treated by applying a Philadelphia collar. Two patients admitted to the hospital in extremis died before definitive treatment of their cervical spine lesions could be instituted.

Of the 25 nonmoribund patients having spinal cord damage, 13 were treated by halo traction alone and 12 by spinal fusion, with decompression in two cases. There was no difference in the eventual degree of return of neurologic function between the two groups.

Discussion

Cause and Diagnosis

A comparison of the demographic, etiologic and diagnostic details of the patients in our series with those of three other series collected in the US in recent years is shown in Table 3. Although these series are not wholly comparable as one of them somewhat antedates the others and relates only to patients with spinal cord damage,[4] they have many similarities, some, but not all, of which they share with earlier studies and those from other countries. This suggests that the characteristics of the traumatic lesions of the cervical spine are determined by more than one set of factors, one of which remains constant between series, while the others vary.

Anatomic considerations. Despite great differences in the conditions responsible for cervical spine injuries—such as the speed of motor traffic—over the past 60 years, the frequency distribution of the vertebrae involved in our cases of major fracture of the cervical spine (Table 1) is very similar to that reported by Jefferson in 1925.[14] He noted that the most common site of fractures of the cervical spine was toward its lower end, but predicted from indications in his own data that a second peak would be found at C1-2. These two peak frequencies have since been identified in other series,[1,2,5] as well as in our own.

Spinal cord damage is found significantly less often in patients with lesions at C1-2 than in those with lower cervical damage. Bohlman noted cord damage in only 11/69 patients with lesions at C1-2 but in 167/229 of those with lesions at C-3 to C-7 ($P < .001$).[3] In our series the proportions were 2/26 for C1-2 lesions and 22/63 for major injuries at C-3 to C-7 ($P < .01$). This may reflect a combination of two factors. On the one hand complete cord lesions at this level are often immediately fatal, but also the spinal canal is relatively wide in relation to the diameter of the spinal cord, so that only cases with gross displacement of the vertebrae—implying very severe trauma—suffer cord damage.

The frequency distribution of the minor fractures of the cervical spine differs significantly (degrees of freedom = 6, $P = .02$) from that of the major fractures, showing no peak at the upper end of the spine. This may be because many of these were avulsion injuries of the transverse and spinous processes, associated with trauma to the upper limb girdle. The statistically significantly ($P < .05$) increased incidence of trauma to other systems in cases of minor compared with major cervical injury might appear paradoxic. It probably merely indicates that few patients who have sustained minor neck trauma without other injuries are admitted to hospital.

Epidemiologic features. Cervical spine injuries largely affect young people: in four recent North American series (Table 3) and in one from Australia,[6] the median age of the victims was 25 years with mean ages between 28 and 35 years, while in Whitley and Forsyth's[5] series the mean age was 31 years. In all these, male victims outnumbered female victims in a ratio of about 4 to 1. In Scotland, Harris and colleagues[15] found a similar sex ratio, though the median age of their patients was about 40 years. Riggins and Kraus found that of 79 patients with cervical spine trauma admitted (not always initially) to a group of county hospitals in California, only 51% were male whereas 33% were women older than 65 years, but this was plainly a highly selected population.[16]

The proportion of patients injured in traffic accidents has varied considerably between series, doubtless reflecting differences in the life-styles of the populations studied. A larger percentage of patients was injured in traffic accidents in the Kentucky series[10] and particularly in our Arizona series than in those from southern California[4] or Maryland.[11] In the southern California series[4] the excess of traffic accidents was replaced by sports injuries and in that from Maryland[11] by falls (from high-rise buildings? Relatively fewer buildings in the Southwest than in the East are more than one story high). In a recent series from Edinburgh, Scotland—also a city of multistory buildings—20% of the injuries were due to falls and only 46% to traffic accidents.[15]

The proportion of patients who had been driving or riding in automobiles compared with those riding motorcycles and those who were pedestrians was fairly constant between series, but it can be shown that in ours, at least, the risk of neck injury to persons riding a motorcycle was six times greater than to those in a car. In Pima County, Arizona, where most of our patients were injured, motorcycles numbered only about 2.8% of all vehicles registered during the period of this study, while the mean number of occupants of all cars and trucks involved in accidents was 1.46 and for motorcycles it was 1.07 (Ms. Gail Brown, Accident Record Unit, Arizona Department of Transportation, oral communication, June 1986). Thus one might expect that motorcycle riders would account for about 2.05% of patients injured in traffic accidents. In fact, however, they comprised 11/86 (12%) of all persons injured in traffic-related accidents for whom adequate information is available, a significant excess ($P < .001$).

The continuing occurrence of severe neck injuries during water sports also gives cause for concern. Heiden and coworkers found that 23% of cases occurred in this way, including 17% sustained while diving,[4] and in the series of Soderstrom and associates, which also contained a large proportion (72%) of spinal cord injuries, 17% were diving accidents.[11] Although among our patients only seven were involved in diving accidents, three of them suffered permanent spinal cord damage. The necessity for continuing public education on the danger of diving into shallow water cannot be overstressed.

Situation of the admitting hospital. The experience that is

TABLE 3.—*Patient Populations, Causes and Patterns of Injury in 4 Recent US Series of Major Cervical Spine Injury**

Years of Survey	California† 1963-1972	Maryland‡ 1976-1982	Kentucky§ 1979-1984	Arizona‖ 1980-1985
Patients, No.	356	288	88	93¶
Mean age, yr	NS	35	28	30
Median age, yr	25	NS	25	25
Male patients, %	83	85	83	81
Vehicle injuries, %	50	53	72	79
Auto riders, %	43	50	65	68
Motorcyclists, %	5		5	9
Pedestrians, %	2	3	2	2
Falls, %	12	22	11	6
All sports, %	29	NS	9	10
Diving, %	17	17	NS	8
Other causes, %	9	7	8	5
Major associated injuries, %	NS	25	60	44
Spinal cord damage, %	(100)	72	36	29

NS = not stated

*Percentages are given as whole numbers.
†From Heiden et al.[4]
‡From Soderstrom et al.[11]
§From Reiss et al.[10]
‖This study.
¶Major injuries only.

gained in a particular hospital of any sort of injury will be partly a function of its special purpose and facilities.[4,9,15] Another relevant factor is a hospital's geographic location. In Table 4 we have compared our series with that reported by Reiss and colleagues.[10] The data for both were collected during much the same period of time. They are almost identical in size, in the median ages of the patients and in the proportion of male victims in each series. The frequencies of the various causes of injury are also closely comparable. Yet there is a noticeable "shift to the right" of the spectrum of severity of injury in Reiss and co-workers' series compared with that of ours. The proportion of their patients suffering a neurologic deficit was significantly higher than ours, and more of their patients suffered a major associated injury ($.02 > P > .01$). Their patients suffered, on average, 2.3 major associated injuries each, whereas in ours the incidence was only 1.8, and nine of them died compared with only five of ours. Reiss and associates were plainly dealing with a more gravely injured series of people overall than we were. A likely explanation lies in the relative locations of their hospital and ours. Our hospital lies near the center of population of Tucson, but is not the closest hospital to the single freeway that traverses the city, and during the period covered by this report it had not been designated as a trauma center. By contrast, the hospital of Reiss and associates stands close to the intersection of two major crowded highways on which high-speed accidents are frequent (H.D. Garretson, MD, University of Louisville [Ky] School of Medicine, oral communication, June 1986). Severe intra-abdominal and intrathoracic injuries are known to occur more frequently in this type of accident than, for example, in sports injuries.[11]

Management

Soderstrom and colleagues found intra-abdominal injuries in 3 out of 58 patients who were in shock and had neurologic deficits following spinal cord trauma[11]; they emphasized that intra-abdominal and spinal cord lesions may occur together. They also reported three cases of "false-positive" peritoneal lavage, however. This fact, together with the two instances of negative laparotomy in our series, indicates that in interpreting an equivocal abdominal paracentesis in patients with upper cervical cord lesions, due weight must also be given to the fact that these often lead to gross arterial hypotension due to a loss of vasomotor control.

The efficacy of steroid therapy in the management of acute injuries of the spinal cord remains controversial.[17] In our series all such patients received some steroids, but the variety of drugs and dosages rendered the data unsuitable for statistical analysis. As already noted, there was no indication that one particular protocol was either more or less effective than the others. The most usual regimen was 100 mg methylprednisolone per 24 hours. None of the patients received amounts of steroid approaching 7 grams methylprednisolone or an equivalent in the first 24 hours, as some have urged.[18]

The proportion of our patients treated by an operation—40% of those with major cervical injuries—is very similar to that reported by Young and Dexter.[19] In both series the main reason for intervention was to stabilize a fracture or dislocation to allow earlier rehabilitation. Our finding that early surgical treatment has no effect on the ultimate degree of recovery of cord function agrees with the majority opinion.[15,19,20] Only one recent report claims a favorable effect for early surgical fixation of the cervical spine,[21] and in this paper, although a group of surgically treated patients subsequently attained higher motor test scores than a conservatively treated group, their scores on admission were also higher, and it can be calculated from the data that the improvement in scores was no greater for one group than for the other.[22] This finding and the considerable differences in the severity of both the cervical spine lesions themselves and their complications that appeared between two such outwardly similar series of cases as Reiss and associates[10] and our own underline the necessity for extreme caution in comparing the results of treatment of any but randomly selected series of patients.

TABLE 4.—Percentage Frequencies (Whole Numbers) of Associated Lesions in Patients With Major Cervical Spine Trauma

	Present Series (93 cases)	Reiss et al, 1986[4] (88 cases)
Neurologic deficits	34	45
Associated injuries		
Extraneural head	25	64
Intracranial	12	67
Spine (not cervical)	4	6
Thoracic	17	46
Abdominal	10	26
Extremities	23	23
Total with any associated injury		
1 or more major	44	60
Minor only	14	24
Deaths	5	9

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